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REPORT ON THE STATUS OF CURRENT AND FUTURE RUSSIAN METEOROLOGICAL SATELLITE SYSTEMS

This document addresses the current status of the Russian satellite systems: Meteor-M N2, N2-2 polar-orbiting meteorological satellites (launched on July 8th, 2014 and July 5th, 2019) and Electro-L N2, N3 geostationary meteorological satellites (launched on December 11th, 2015, December 24th, 2019).

Future Russian geostationary meteorological constellation will consist of three Electro-L series satellites. The satellites are to be placed at 14,5W, 76E and 166E orbital positions. The mission objectives, payload and ground segment details are presented.

Arctica-M project of at least two highly elliptical orbit satellites is also presented. The first spacecraft in HEO Arctica-M N1 was launched on February 28th, 2021, and is now in the commissioning phase. The launch of the second Arctica-M satellite is scheduled for 2023.

STATUS OF CURRENT AND FUTURE RUSSIAN METEOROLOGICAL SATELLITE SYSTEMS

1 INTRODUCTION

According to the Russian Federal Space Program (2016–2025) the space system for hydrometeorological and environmental monitoring will consist of four polar-orbiting meteorological satellites, three geostationary meteorological satellites and four highly elliptical orbit satellites. Currently, four meteorological satellites are operational: Meteor-M N2, N 2-2 (launched in 2014, 2019) and Electro-L N2, N3 (launched in 2015, 2019).

A prospective constellation of Electro-L geostationary satellites to be placed at 14.5W, 76E and 166E orbital positions is presented.

Arctica-M project of at least two satellites at highly elliptical orbits is also presented. The first HEO meteorological spacecraft Arctica-M N1 was launched on February 28th, 2021, and is now in the commissioning phase. The launch of the second Arctica-M satellite is scheduled for 2023. It will provide frequent observations similar to geostationary satellites, but over the Arctic region. The payload of Arctica-M satellites is similar to those of Electro-L series.

2 CURRENT SATELLITE SYSTEMS

Four Russian meteorological satellites are now operational: Meteor-M N2, N 2-2 and Electro-L N2, N3. The first HEO meteorological spacecraft Arctica-M N1 was launched on February 28th, 2021, and is now in the commissioning phase. The satellite status in the WMO tables is updated below.

Current GEO satellites

Sector	Satellite in orbit	Operator	Location	Launch date	Details on near real time access	Instrument payload
Atlantic Ocean	Electro-L N2	Russian Federation /Roshydromet	14,5W	15/12/2015	HRIT/LRIT specification	MSU-GS, GGAK-E, DCS, COSPAS-SARSAT, Direct broadcast HRIT, LRIT
Indian Ocean (36°E-108°E)	Electro-L N3	Russian Federation /Roshydromet	76E	24/12/2019	HRIT/LRIT specification	MSU-GS, GGAK-E, DCS, COSPAS-SARSAT, Direct broadcast HRIT, LRIT

Current LEO satellites

Orbit type	Satellite in orbit	Operator	Equator Crossing Time	Mean Alti-tude	Launch date	Details on near real time access	Instrument payload
Sun-synchronous "Morning" orbit ECT between 19:00-24:00 and between 07:00-12:00	Meteor-M N2	Russian Federation /Roshydro met	09:30 asc	820 km	08/07/2014	Signal structure <http://planet.iitp.ru/english/spacecraft/meteor_m_n2_structure_eng.htm>	MSU-MR, MTVZA-GY, IKFS-2, KMSS, DCS, Severjanin, GGAK-M. Dissemination: HRPT, LRPT
Sun-synchronous "Afternoon" orbit ECT between 01:00-05:00 and between 13:00-17:00	Meteor-M N2-2	Russian Federation /Roshydro met	15:00 asc	821 km	05/07/2019	Signal structure <http://planet.iitp.ru/english/spacecraft/meteor_m_n2_structure_eng.htm>	MSU-MR, MTVZA-GY, IKFS-2, KMSS, DCS, COSPAS-SARSAT, GGAK-M, Dissemination: HRPT, LRPT

Current HEO satellites

Orbit type	Satellite in orbit	Operator	1st apogee longitude	2nd apogee longitude	Launch date	Details on near real time access	Instrument payload
Molniya orbit	Arctica-N N1	Russian Federation /Roshydro met	25 W	155 E	28/02/2021	N/a	MSU-GS/A, DCS/A, GGAK-E

2.1 Status of current GEO satellite systems

In order to provide the coverage of the Indian Ocean region Electro-L N3 geostationary meteorological satellite has been placed at 76 E orbital position, whereas Electro-L N2 was moved to the position of 14.5 W.

2.1.1 Mission objectives, payload/instruments, products

Primary objectives of Electro-L mission:

- Continuous observation of the Earth within a radius of 55-60 degrees centered at the sub-satellite point;
- Simultaneous images of cloud cover and the Earth's surface in 10 visible and infrared channels;
- The development and maintaining the national data collection system (DCS), collection of the hydrometeorlogical data from national and international platforms (DCPs);
- Retransmission of the data from Roshydromet regional centers;
- Heliogeophysical measurements at geostationary orbit altitudes;
- Data dissemination in HRIT/LRIT formats to national and foreign users.

Besides standard meteorological communication package (DCS and re-transmitters) the key payload consists of MSU-GS imager that provides data in three visible and seven IR channels. The spatial resolution at sub-satellite point is 1 km for visible and 4 km for IR channels. The period between scanning sessions for all channels is 30 min (regular operation) or 15 min (frequent mode). The MSU-GS instrument is manufactured by JSC "Russian Space Systems". The 7.5 GHz channel with of 30.72 Mbps data rate is used for raw data downlink.

GGAK Heliogeophysical Measurements Suite provides monitoring of the electromagnetic solar radiation, corpuscular radiation and terrestrial magnetic fields. The 1.7 GHz channel (5 Kbps data rate) is used for GGAK data transmitting.

Besides general downlink for the raw hydrometeorological data, there are also following retransmission channels onboard:

- DCP network data collection and retransmission channel;
- Retransmission channel for hydrometeorological data exchange between regional Roshydromet centers;
- Channels for MSU-GS data dissemination in HRIT and LRIT formats;
- COSPAS-SARSAT Search & Rescue system.

2.1.2 Status of spacecraft

The current status of Electro-L N2 satellite:

- The MSU-GS instrument is functional with limitations (12 mkm channel is absent);
- The DCS is functional;
- The COSPAS-SARSAT system is functional;
- The GGAK-E instrument is functional;
- The HRIT/LRIT data is being distributed via the land channels, including Internet channels.

The current status of Electro-L N3 satellite:

- The MSU-GS instrument is functional;
- The DCS is functional;
- The COSPAS-SARSAT system is functional;
- The GGAK-E instrument is functional;
- The HRIT/LRIT data is being distributed via the land channels, including Internet channels.

2.1.3 Impact on spacecraft due to space weather

Impact on spacecraft due to space weather was not positively established.

2.1.4 Ground segment

Geographically Distributed System for Earth Monitoring from Space of Roshydromet as a part of Integrated Geographically Distributed Information System of Earth Remote Sensing (IGDIS ERS) is based on three SRC Planeta satellite centers, responsible for receiving, processing, disseminating and archiving of satellite data: European (Moscow-Obninsk-Dolgoprudny), Siberian (Novosibirsk) and Far-Eastern (Khabarovsk). These centers together provide Roshydromet and its users with full operational coverage of all the Russian Federation and neighboring territories.

Core ground segment for Electro-L series satellites is located at SRC Planeta facilities. The receiving stations together with retransmission systems are located in European center (Dolgoprudny) and Siberian center (Novosibirsk) and Far-Eastern center (Khabarovsk).

The ground segment for Electro-L series satellites also includes the network of DCP, LRIT and HRIT stations.

Satellite data is also being received at Roscosmos facility in Moscow for the quality control purposes.

2.1.5 Data transmission

The Electro-L N2 and N3 HRIT/LRIT data is being distributed via the land channels, including Internet channels, and also provided to EUMETSAT in near real time.

Additionally, the satellite is used for COSPAS-SARSAT Search & Rescue signal retransmission at 0.4/1.54 GHz waveband.

Russian DCS relies on Electro-L N3 services and backed up by Luch-5B communication satellite. There are 686 DCPs currently deployed by Roshydromet. Those DCPs are being used at both manned and unmanned hydrometeorological stations all over Russian Federation, each usually operates 8 times a day, with an option for frequent mode (a message each 2 minutes, so called “storm” mode). Messages contain standard meteorological and hydrological measurements. Usage statistics for DCS is being accumulated and analysed at SRC Planeta, Moscow.

2.1.6 Projects, services

The list of services currently provided by Electro-L series satellites:

- Visible and IR imagery of MSU-GS instrument;
- DCS;
- GGAK Heliogeophysical Measurements Suite;
- COSPAS-SARSAT system.

2.2 Status of current LEO satellite systems

The second spacecraft of Meteor-M series of the Russian polar-orbiting meteorological satellites, Meteor-M N2 was launched on July 8th, 2014. It is located in a sun-synchronous orbit (820 km, ascending, equator crossing time ~ 9:30, inclination 98.79°). The satellite was designed and built by JSC "VNIIEM Corporation". The polar-orbiting Meteor-M N2-2 was launched (to the afternoon orbit) on July 5th, 2019. Meteor-M N2-2 is operational with limitations.

2.2.1 Mission objectives, payload/instruments, products

The main objective of Meteor-M mission is to provide global observations of the Earth's surface and the atmosphere. The data acquired by the satellite is used for the following purposes:

- Weather analysis and forecasting on global and regional scales;
- Global climate change monitoring;
- Sea surface observations;
- Space weather analysis and prediction (solar wind, ionosphere research, Earth's magnetic field, etc.).

Meteor-M N2, N2-2 payload includes:

- MSU-MR Scanning Radiometer (1 km spatial resolution multichannel scanning unit, 6 channels, VIS/IR);
- KMSS VIS Scanning Imager (6 channels implemented by 3 cameras, 50 m and 100 m spatial resolution);
- Severjanin X-band Synthetic Aperture Radar (onboard only Meteor-M N2);
- MTVZA-GY Imaging/Sounding Microwave Radiometer (module for temperature and humidity sounding of the atmosphere, 26 channels, 10.6-183 GHz);
- IKFS-2 - IR Fourier-transform spectrometer (IR atmospheric sounder, spectral range 5-15 μm, spectral resolution ~ 0.5 cm^{-1});
- GGAK-M Heliogeophysical Measurements Suite;
- Data collection system (DCS).

Meteor-M N2, N2-2 has three downlink radio lines:

- 2-channel X-band radio link (8.192 GHz and 8.320 GHz) with 122.88 Mbps data transmission rate in each channel;
- L-band radio link (1.7 GHz) with 665.4 Kbps data transmission rate (HRPT data transmission);
- VHF-band radio link (137 MHz) with 80 Kbps data transmission rate (LRPT data transmission).

2.2.2 Status of spacecraft

Meteor-M N2 is operational.
Instrument status:

- MSU-MR instrument is functional;
- MTVZA-GY instrument has failed in 2017;
- KMSS instrument is functional;
- IKFS-2 instrument is functional;
- Severjanin SAR instrument is functional with limitations;
- DCS is functional;
- LRPT transmission is functional;
- GGAK-M is functional.

Meteor-M N2-2 is operational with limitations.
Instrument status:

- MSU-MR instrument is functional;
- MTVZA-GY instrument is functional with limitations;
- KMSS instrument is functional;
- IKFS-2 instrument is not functional;
- DCS is not functional;
- LRPT transmission is functional;
- GGAK-M is functional with limitations.

2.2.3 Impact on spacecraft due to space weather

Impact on spacecraft due to space weather was not established.

2.2.4 Ground segment

Geographically Distributed System for Earth Monitoring from Space of Roshydromet as a part of IGDIS ERS is based on three SRC Planeta satellite centers, responsible for receiving, processing, disseminating and archiving of satellite data: European (Moscow-Obninsk-Dolgoprudny), Siberian (Novosibirsk) and Far-Eastern (Khabarovsk). These centers together provide Roshydromet and its users with full operational coverage of all the Russian Federation and neighboring territories with the lowest possible latency.

Core ground segment for Meteor-M series satellites is located at SRC Planeta facilities. It also includes the network of DCS, LRPT and HRPT stations. Data acquisition and processing are also performed by Roscosmos operational facility in Moscow.

Meteor-M N2 ground segment has been developed jointly by Roshydromet and Roscosmos.

2.2.5 Data transmission

Global data X-band downlink is used for Roshydromet purposes only (raw data dumps over the SRC Planeta centers).

The direct broadcast is operational in L-band in HRPT-like format. The detailed format description is published at SRC Planeta WEB-site.

The preprocessed data is also distributed to Roshydromet users via SRC Planeta FTP server.

The IKFS-2/Meteor-M N2 data is available to EUMETSAT in near-real time via landline.

2.2.6 Projects, services

The list of services currently provided by the Meteor-M series satellites:

- Visible and IR imagery (MSU-MR);
- Moderate resolution visible imagery (KMSS);
- Temperature and humidity sounding (MTVZA-GY) onboard Meteor-M N2-2 only;
- Atmospheric sounding (IKFS-2) onboard Meteor-M M2 only.

Meteor-M N2, N2-2 data is used for atmospheric sounding, disaster monitoring such as floods and forest fires, as well as sea ice and water pollution monitoring, etc.

2.2.7 User statistics

Meteor-M N2, N2-2 satellite data is currently used internally by Russian Hydrometeorological and Environmental Monitoring Service, and also provided to EMERCOM – Ministry of Civil Defense, Emergencies and Disaster Relief of the Russian Federation, Ministry of Natural Resources and Environment of the Russian Federation and other federal and regional institutions of Russia.

3 FUTURE SATELLITE SYSTEMS

Sector	Satellite in orbit	Operator	Location	Planned launch date	Instrument payload
TBD	Electro-L N4	Russian Federation /Roshydromet	TBD	2022	MSU-GS, GGAK-E, DCS, COSPAS-SARSAT, Direct broadcast HRIT, LRIT
TBD	Electro-L N5	Russian Federation /Roshydromet	TBD	2023	MSU-GS, GGAK-E, DCS, COSPAS-SARSAT, Direct broadcast HRIT, LRIT

Orbit type	Satellite in orbit	Operator	Orbit	Planned launch date	Instrument payload
	Arctica-M N2	Russian Federation /Roshydromet	Molnya Orbit	2023	MSU-GS/HE, DCS, GGAK
	Arctica-M	Russian Federation	Molnya Orbit	2025	MSU-GS/HE,

	N3	/Roshydromet			DCS, GGAK
	Arctica-M N4	Russian Federation /Roshydromet	Molnya Orbit	2026	MSU-GS/HE, DCS, GGAK
	Arctica-M N5	Russian Federation /Roshydromet	Molnya Orbit	2027	MSU-GS/HE, DCS, GGAK

Orbit type	Satellite in orbit	Operator	Orbit	Planned launch date	Instrument payload
Sun-synchronous orbit ECT 09.00 (The descending unit)	Meteor-M N2-3	Russian Federation /Roshydromet	820,7	2021	MSU-MR, MTVZA, IKFS-2, KMSS, MeteoSAR, GGAK-M2, DCS, COSPAS-SARSAT Dissemination: HRPT, LRPT
Sun-synchronous orbit ECT TBC	Meteor-M N2-4	Russian Federation /Roshydromet	820,7 km	2022	MSU-MR, MTVZA, IKFS-2, KMSS, MeteoSAR, GGAK-M2, DCS, COSPAS-SARSAT Dissemination: HRPT, LRPT
Sun-synchronous orbit ECT TBC	Meteor-M N2-5	Russian Federation /Roshydromet	820,7 km	2024	MSU-MR, MTVZA, IKFS-2, KMSS, MeteoSAR, GGAK-M2, DCS, COSPAS-SARSAT Dissemination: HRPT, LRPT
Sun-synchronous orbit ECT TBC	Meteor-M N2-6	Russian Federation /Roshydromet	820,7 km	2025	MSU-MR, MTVZA, IKFS-2, KMSS, MeteoSAR, GGAK-M2, DCS, COSPAS-SARSAT Dissemination: HRPT, LRPT

3.1 Status of future GEO satellite systems

According to the Russian Federal Space Program Electro-L constellation of the geostationary meteorological satellites should consist of three similar satellites.

The satellites are designed and built by Lavochkin Association and have a three-axis stabilized platform.

The payload of Electro-L constellation is similar to Electro-L N2, N3 spacecrafts but with improved instrument performance. The payload will consist of MSU-GS imager, standard meteorological communication package (DCS and retransmitters), data retransmission channel for hydrometeorological data exchange between Roshydromet centers, and GGAK Heliogeophysical Measurements Suite.

3.1.1 Mission objectives, spacecraft, payload/instruments, products

Primary objectives of Electro-L missions:

- Continuous observation of the Earth within a radius of 55-60 degrees centered at the sub-satellite point;
- Simultaneous images of cloud cover and the Earth's surface in 10 visible and infrared channels;
- The development and maintaining DCS, collection of the hydrometeorological data from national and international platforms;
- Retransmission of the data from Roshydromet regional centers;
- Heliogeophysical measurements at geostationary orbit altitudes;
- Data dissemination in HRIT/LRIT formats to national and foreign users.

Besides standard meteorological communication package (DCS and retransmitters) the key payload will consist of MSU-GS imager which provides data in three visible and seven IR channels. The spatial resolution at the sub-satellite point is 1 km for visible and 4 km for IR channels. The regular period between scanning sessions for all channels is 30 min or 15 min in frequent mode. The instrument is manufactured by JSC "Russian Space Systems". The 7.5 GHz channel with data rate of 30.72 Mbps is used for raw MSU-GS data downlink.

GGAK Heliogeophysical Measurements Suite provides monitoring of the electromagnetic solar radiation, corpuscular radiation and terrestrial magnetic fields. The separate 1.7 GHz channel (5 Kbps data rate) is used for GGAK data downlink.

Besides general downlink for the raw hydrometeorological data, there are also following retransmission channels onboard:

- DCP network data collection and retransmission channel;
- Retransmission channel for hydrometeorological data exchange between regional Roshydromet centers;
- Channels for MSU-GS data dissemination in HRIT and LRIT formats;
- COSPAS-SARSAT Search & Rescue system.

3.1.2 Ground segment

Electro-L N4, N5 ground segment will be jointly developed by Roshydromet and Roscosmos. Core ground segment for Electro-L satellites will be based on SRC Planeta facilities. The ground segment will also include the network of DCP, LRIT and HRIT stations.

3.1.3 Data transmission

Electro-L N4, N5 HRIT/LRIT channels will be used for the data transmission in L-band every 30 min. Additionally, the satellite will support COSPAS-SARSAT Search and Rescue system at 0.4/1.54 GHz.

3.2 Status of future LEO satellite systems

According to the Russian Federal Space Program (2016–2025) the polar-orbiting satellites system should consist of three hydrometeorological and one oceanographic satellites.

It is planned to launch from five similar satellites with the same payload as Meteor-M N2-2, i.e. Meteor-M N2-3, Meteor-M N2-4, Meteor-M N2-5 and Meteor-M N2-6. The goal is to create a constellation of identical operational meteorological satellites in morning and afternoon orbits. These satellites are to be manufactured by JSC "VNIIEM Corporation". Starting from Meteor N2-3 and Meteor N2-4 among the payload there will be MeteoSAR and modified Heliogeophysical Measurements Suite GGAK-M2.

3.3 Status of future HEO [or other] satellite systems

The launch of the second Arctica-M satellite is scheduled in 2023. It will provide frequent observations similar to geostationary satellites, but over the Arctic region. The payload of Arctica-M satellites is similar to Electro-L series.

3.3.1 Mission objectives, spacecraft, payload/instruments, products

The main purposes of the mission are meteorology, oceanography, including ice cover monitoring and disaster monitoring in the Arctic region. To perform operational monitoring of polar regions 24 hours a day each of two satellites will be covering the area for 6.4 hours and then step back for the next one. The repeat cycle time for each satellite is exactly 12 hours. The payload and general design of the satellites are similar to Electro-L series.

The essential feature of Arctica system spacecraft is their mass and power reserves, potentially allows adding various types of complementary instruments, including international ones if agreed upon.

3.3.2 Ground segment

The ground segment for Arctica constellation should be based on SRC Planeta/ Roshydromet facilities in Moscow, Novosibirsk and Khabarovsk.

3.3.3 Data transmission

Data transmission system of Arctica satellites will consist of:

- X-band downlink with data transmission rate of 30.72 Mbit/s;
- L-band downlink especially for the GGAK instrument with data transmission rate of 5000 bit/s;
- DCS retransmission support at 401-403 MHz / 1.7 GHz.

4 CONCLUSION

Russian Federation is currently developing a national constellation of both geostationary and polar orbiting meteorological satellites. It is complemented by the satellites at highly elliptical “Molnya” type orbits for frequent coverage of the northern areas.